



Thermal Interface Comparisons Under Flight-like Conditions

Juan Rodriguez-Ruiz

NASA/Goddard Space Flight Center, Mail code 545,

Greenbelt, MD 20771

Juan.E.Rodriguez-Ruiz@nasa.gov



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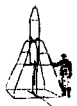
LRO Interface Conductance Test
Juan.E.Rodriguez-Ruiz@nasa.gov



Agenda



- Introduction & Test Goals
- Test Setup
 - Materials & specifications
 - Requirements
 - Configuration
- Original setup lessons learned
- Thermal Interface Materials Background
- Results
- Conclusions & Implementation





Introduction



- Thermal interface materials are used in bolted interfaces to promote good thermal conduction between the two.
- The mounting surface can include panels, heat pipes, electronics boxes, etc...
- On Lunar Reconnaissance Orbiter (LRO) project the results are directly applicable
 - Several high power avionics boxes
 - Several interfaces from RWA to radiator through heat pipe network





Test Goals



- Test interface materials tested were already scheduled to be used on flight or were considered alternatives
- Meet requirements for the Lunar Reconnaissance Orbiter (LRO) project
 - $1W/(in^2 \cdot K)$
- Comparison of commonly used thermal interface materials under more practical conditions
- Test runs according to Lunar Reconnaissance Orbiter Thermal interface material application procedure(451-PROC-001314





Test Runs

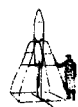


1. Dry joint
2. eGraf HITHERM-1210 (10 mil)
3. NuSil CV-2946 with 5 mil Teflon film
4. ChoSeal -1285
5. Indium
6. Grafoil (5 mil)
7. Copper picture frame with NuSil combination
8. NuSil with spray Teflon
9. Arathane (60% Boron Nitride) with spray Teflon





Test Setup

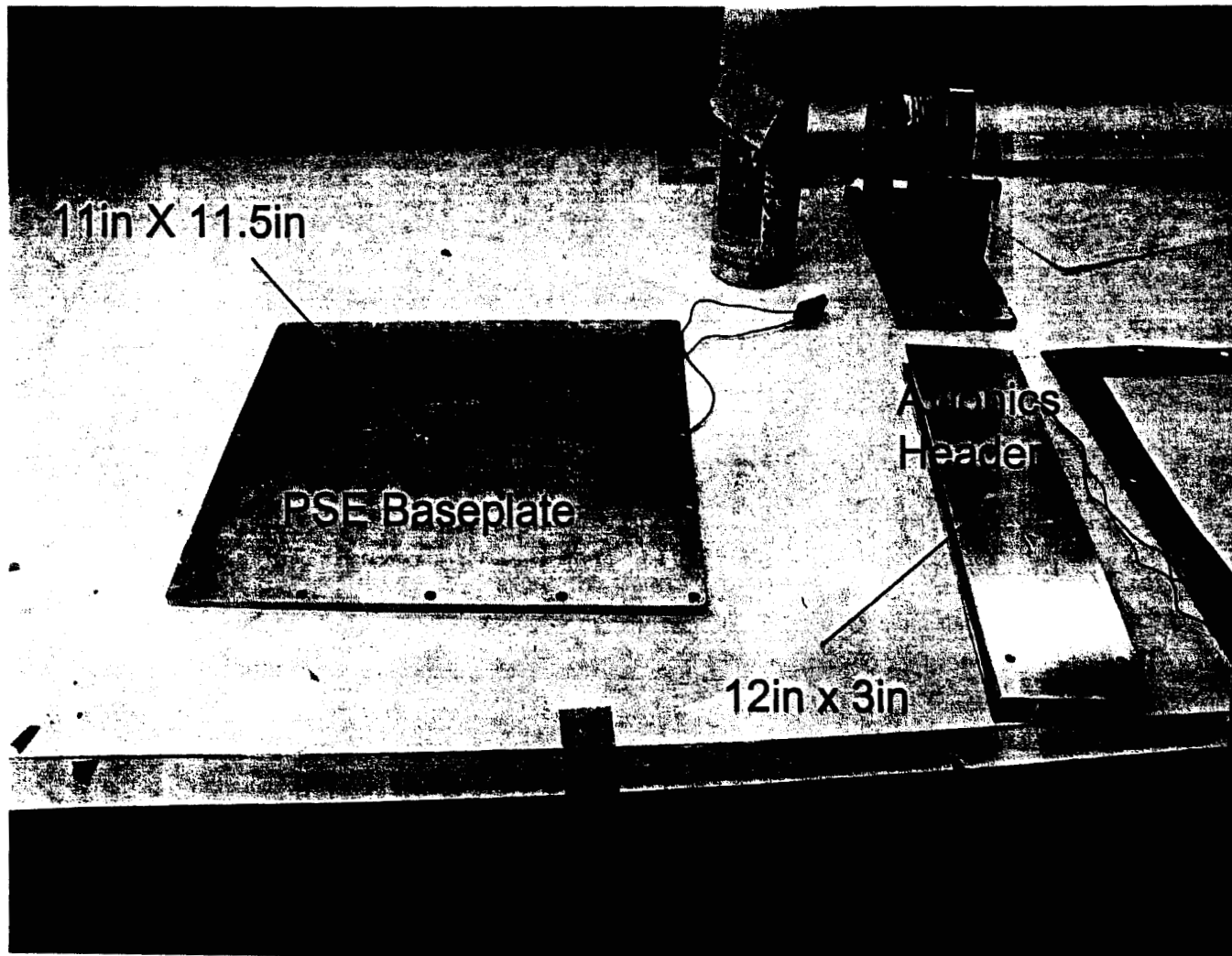


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Tested Surfaces



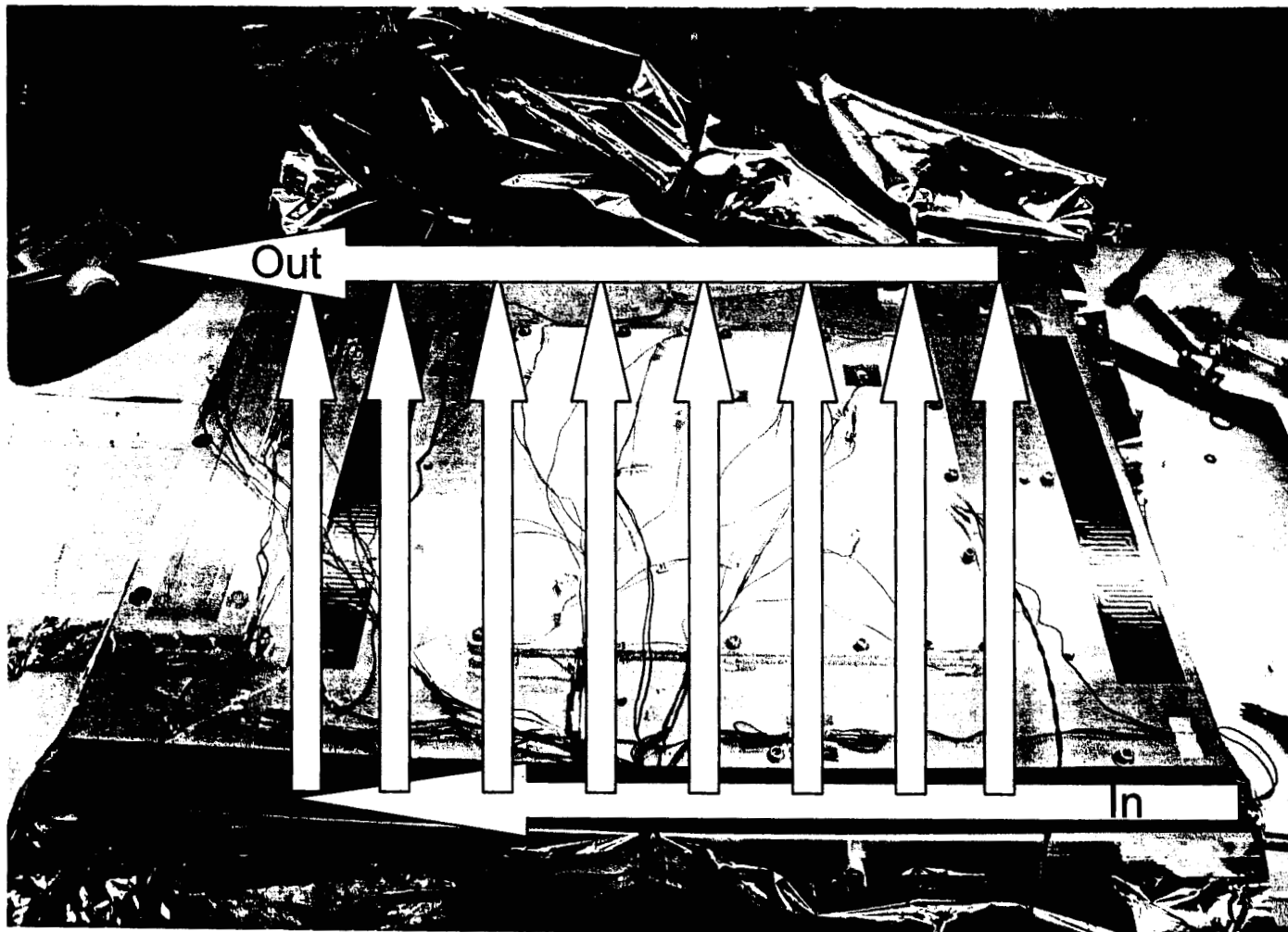


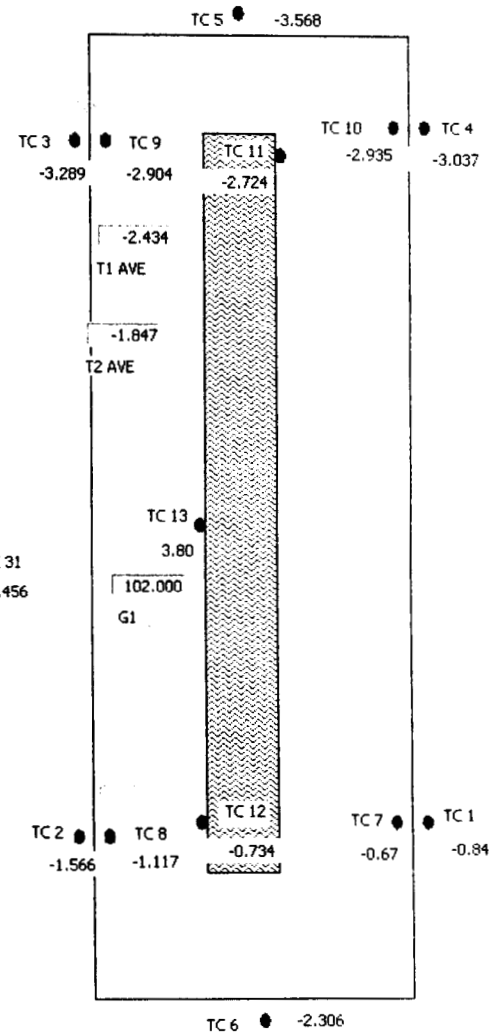
Materials And Specifications



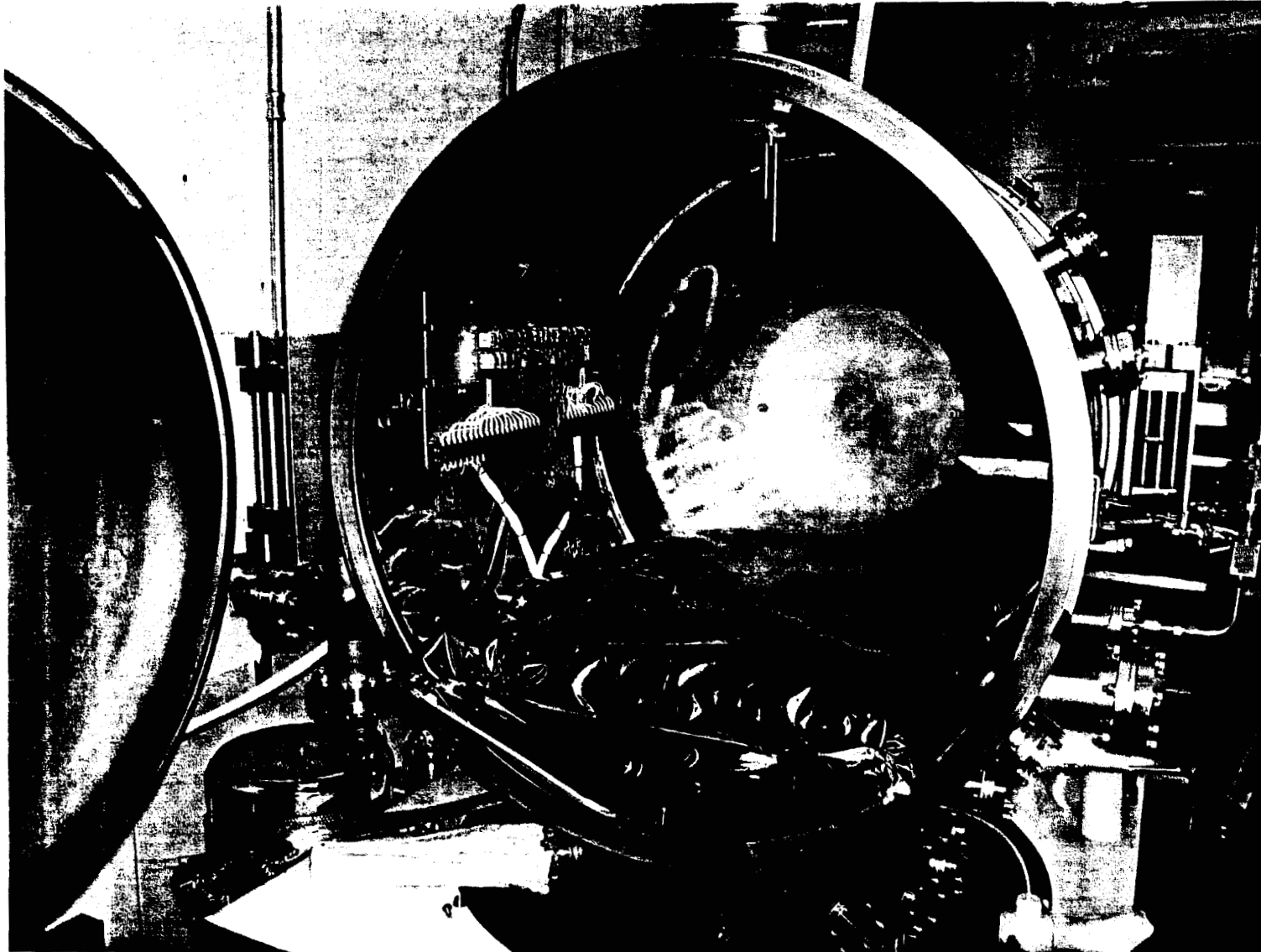
- Thermocouples: Type T (30 AWG) x 35
- Chiller fluid: ~ 30% Propynol & 70% water
- Bolts: Socket-head stainless steel (lubricated with Braycote)
Torque values taken from LRO Torque Spec
 - Heat pipe: 10-32 (30 in-lb)
 - Baseplate: 8-32 (26 in-lb)
- Minco heaters using Pressure Sensitive Adhesive (PSA) and aluminum tape over them. Maximum heater density kept under 3 W/in²
 - Baseplate: 5" X 5" (113.7 Ω)
 - Heat Pipe: 1.5" X 12" (260 Ω)
- Data collection software: Labview 7.1
- Setup covered with MLI to prevent heat loss







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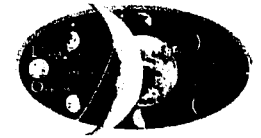


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Test Requirements



- Pressure
 - $< 10^{-3}$ Torr (1 Torr = 133.32 Pa)
 - Controlled by:
 - Mechanical pump
 - LN2 cooled scavenger plate (@ -115°C)
- Steady-state temperature stability criteria
 - ($< 0.5^{\circ}\text{C/hr}$)





Test Configurations

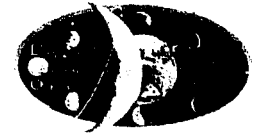


- Two sink temperatures:
 - Cold: -10°C to 0°C
 - Warm: 25°C to 35°C
- Two power levels:
 - Baseplate
 - High: 75 W
 - Low: 50 W
 - Heat Pipe
 - High: 60 W
 - Low: 40 W





Original Setup Lessons Learned!

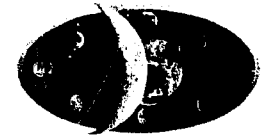


- No use of scavenger plate
- Software problems
- No thorough sanity check of TC's
- Cooling heat exchanger with LN2
 - Too powerful (cooling in short bursts)
- Chiller not cooling enough (added Propynol to increase temperature range)
- Taking data every 2 seconds
- Heater power too low

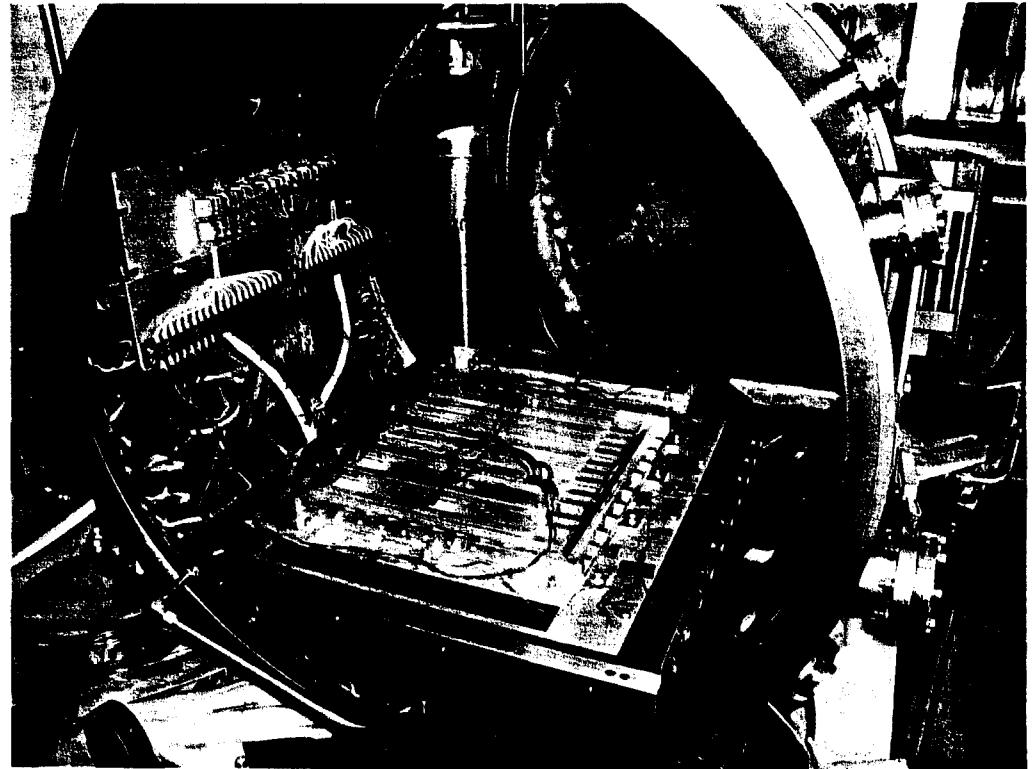
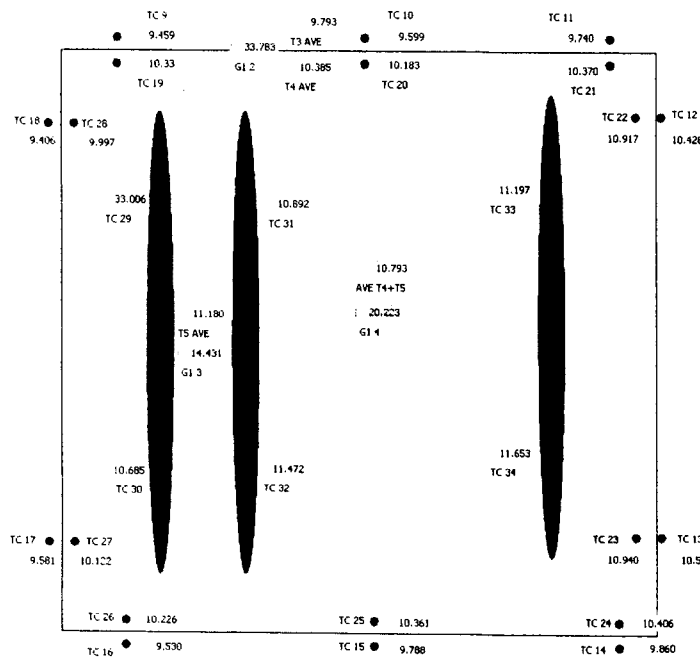




Original Setup Lessons Learned!



- Original base plate used was spare SDO CDH baseplate in an attempt to capture actual box stiffness
 - Uncomfortable and non-uniform heater locations
 - Not very flat surface





Interface Materials



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eGraf

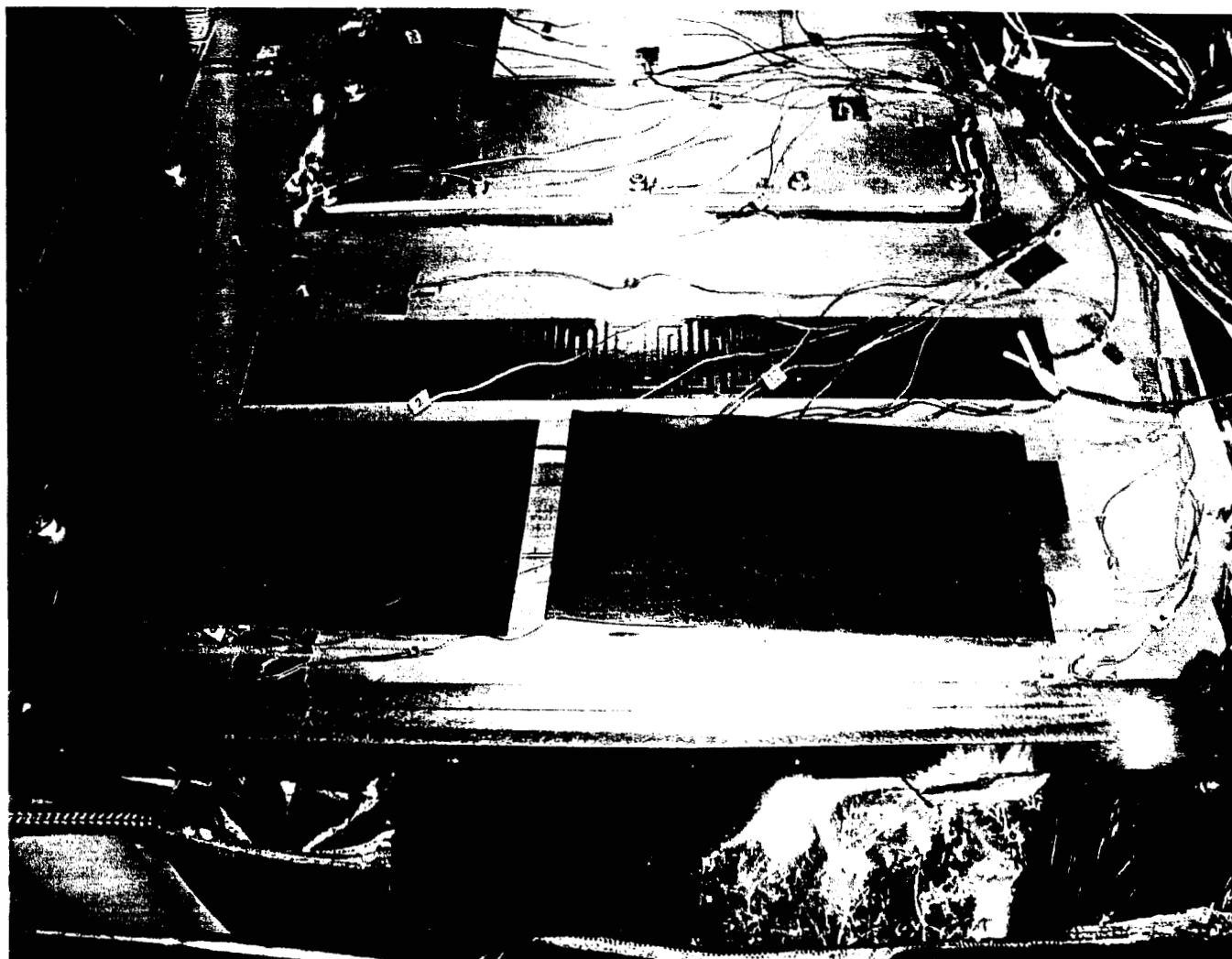


- HITHERM-1210
- Expanded carbon sheet
 - Provides good thermal contact under regular pressure
 - Can be a particulate shedding material
 - 10 mil thick (0.01in)
- Test setup:
 - Baseplate: Four 6"X 6" sheets
 - Heat pipe: Two 3"X 6" sheets





eGraf



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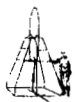
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ChoSeal -1285



- Silicone sheet loaded with silver-plated aluminum particles to provide good thermal and electrical conduction
- Good thermal contact relies on a squeezing pressure so it does not perform well away from bolts and clamps
- 20 mil thick
- Bake out required for better performance (at 175°C in an air oven for 24 hours)

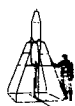
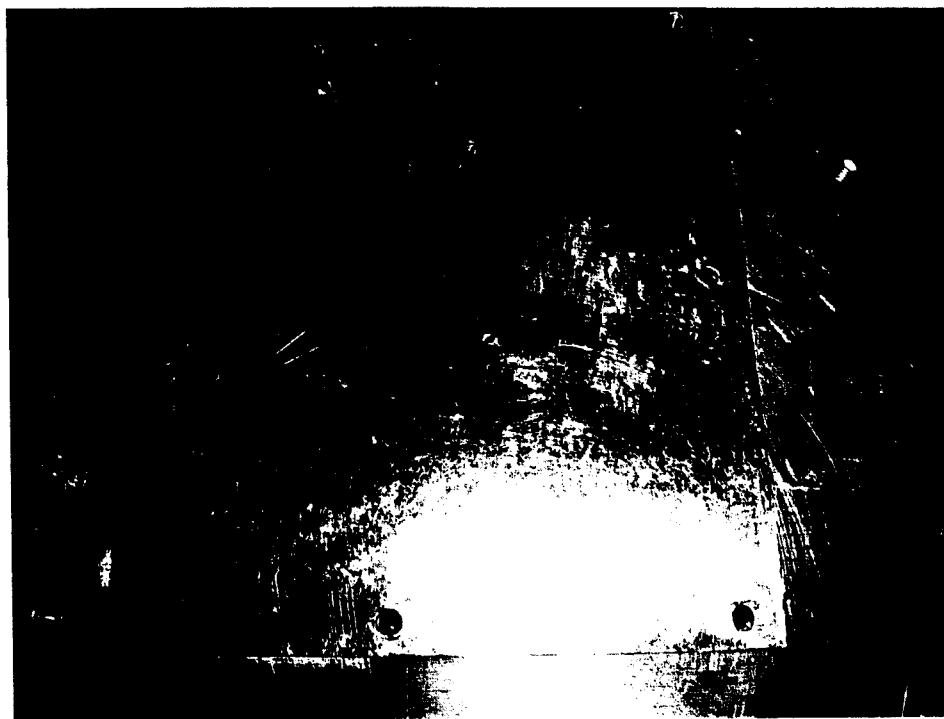




Indium



- 99.99% Indium foil
- No sample shown:
 - Carcinogenic
 - Skin irritant
- Lustrous silver-white metal
- Soft, malleable and ductile





NuSil

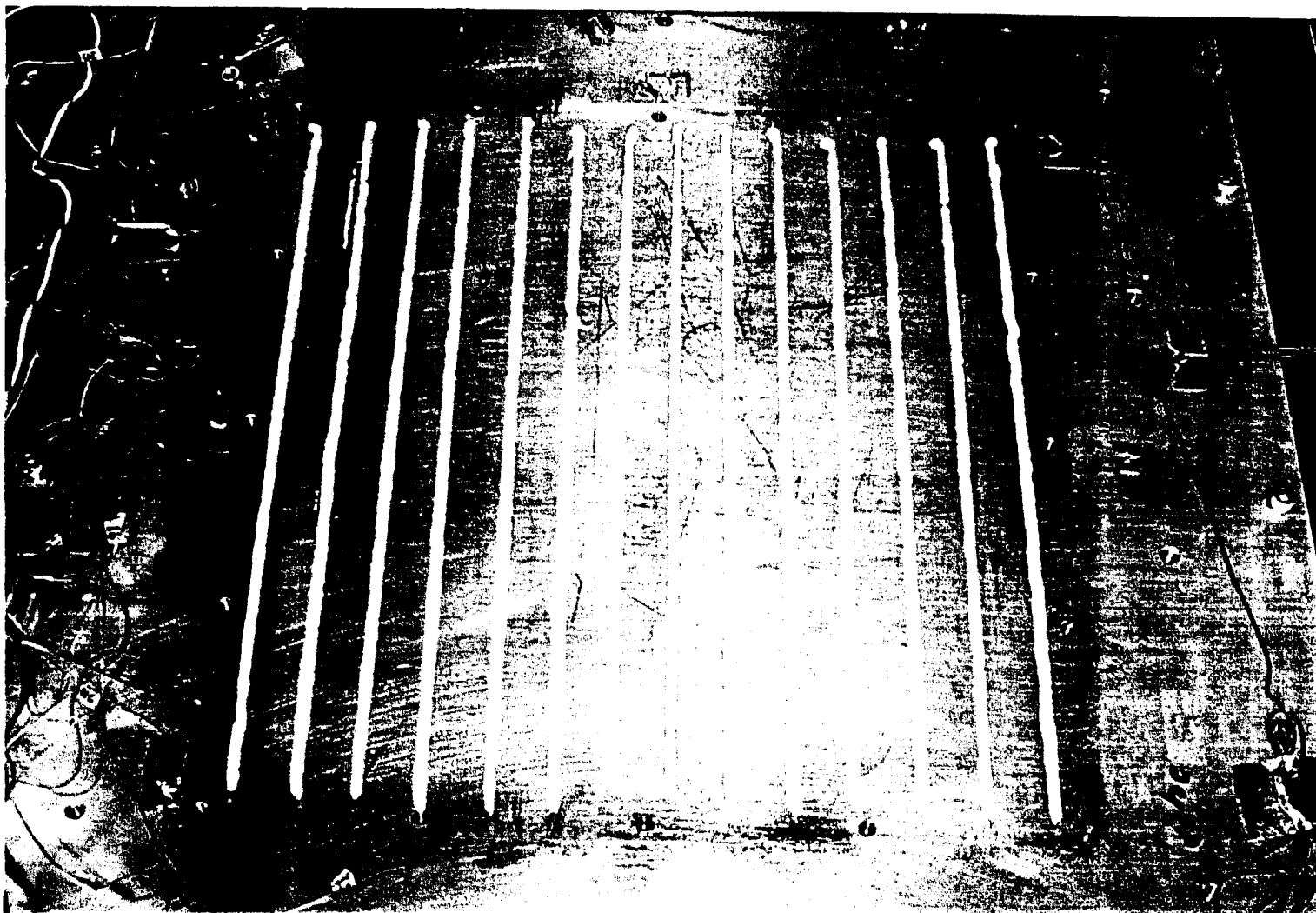


- CV-2946
- It is a silicone based fluid (may pose a contamination risk)
- Stored in 5cc syringes at very low temperatures and thawed before application.
- It conforms to the shape of the interface then it solidifies at room temperature.
- Test setup:
 - Teflon film 5 mil (0.005 in)
 - Strips: ~1/8" wide, 1" between strips





NuSil

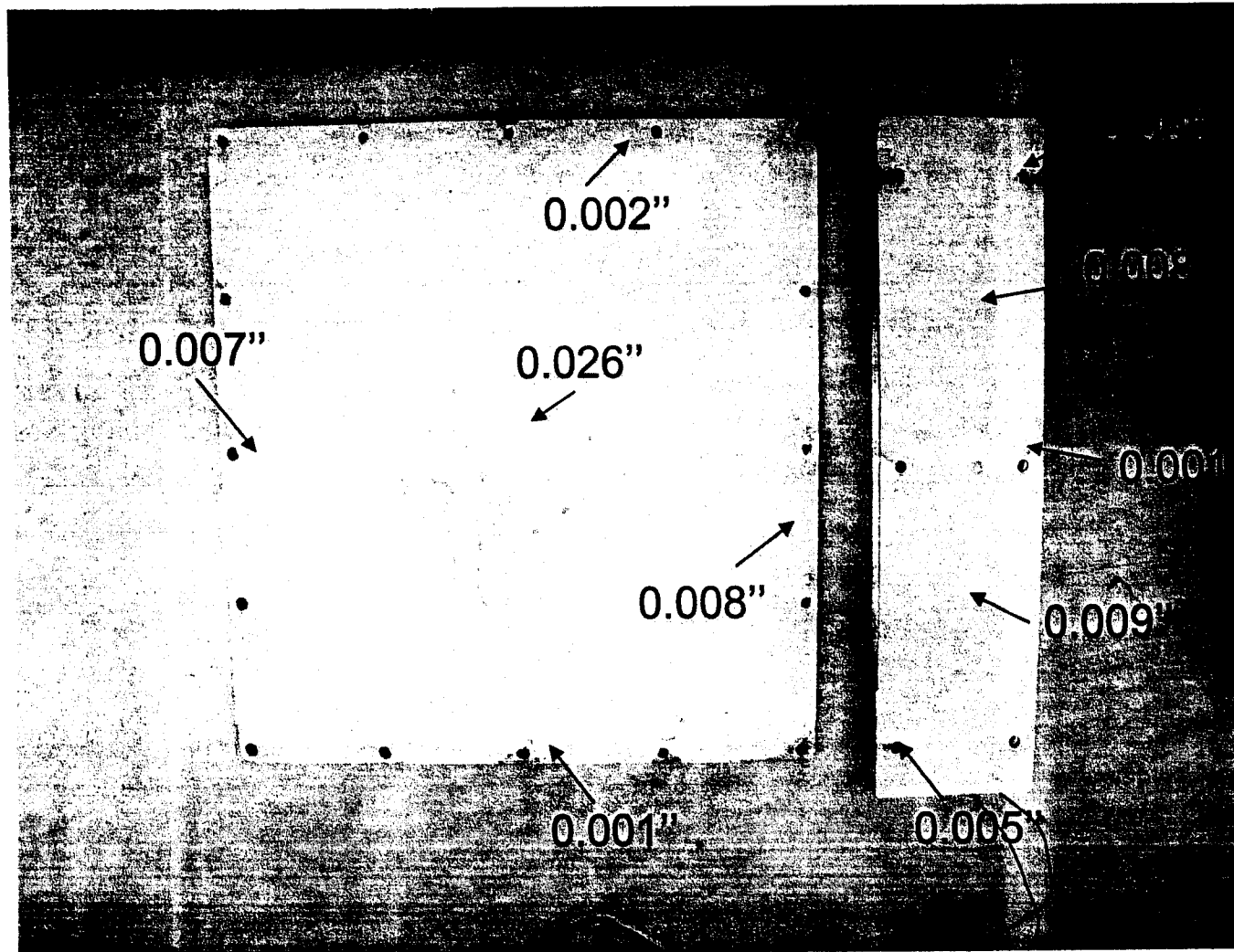
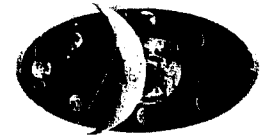


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NuSil

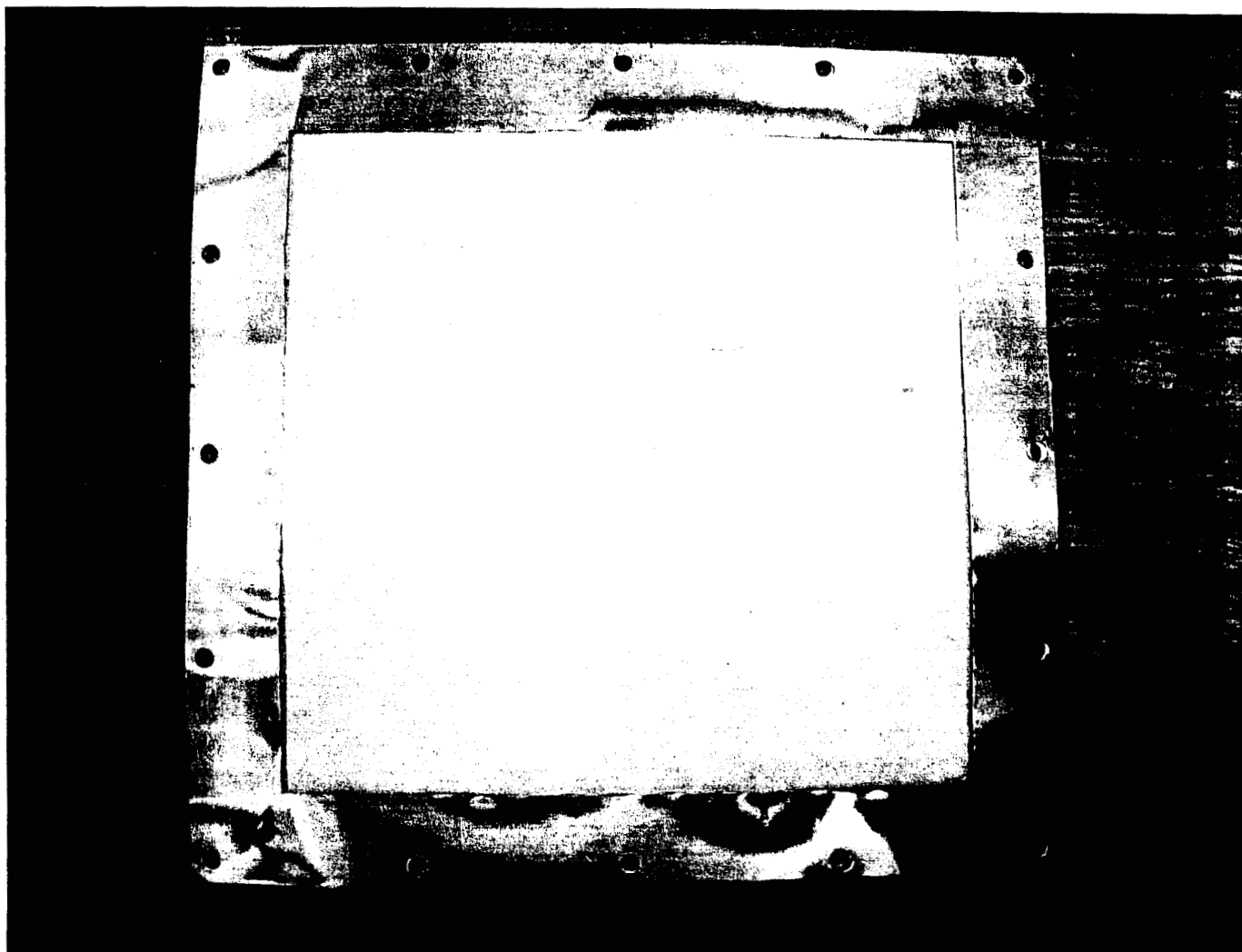


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Copper Picture Frame With NuSil





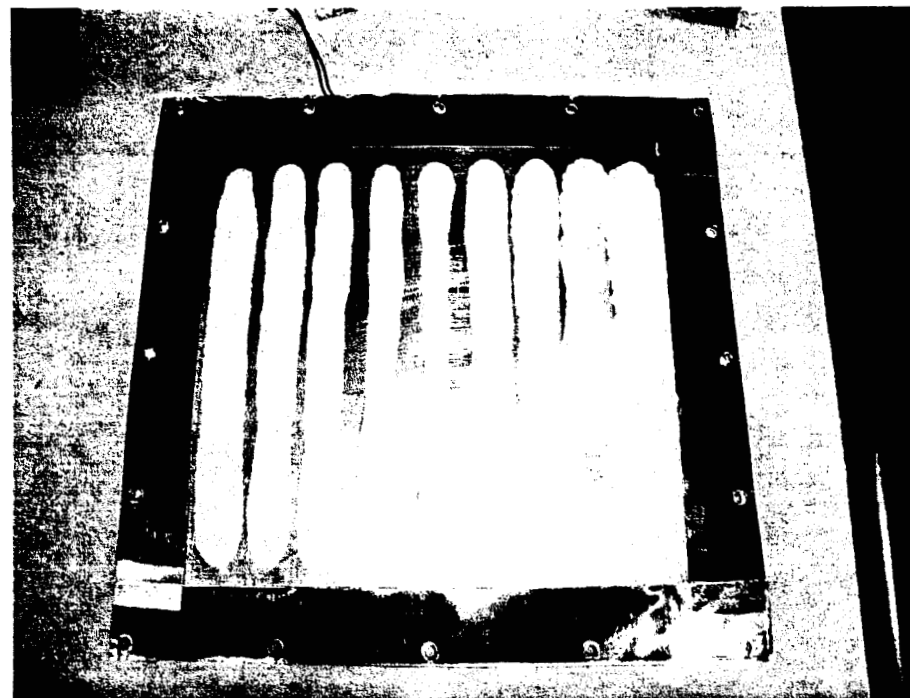
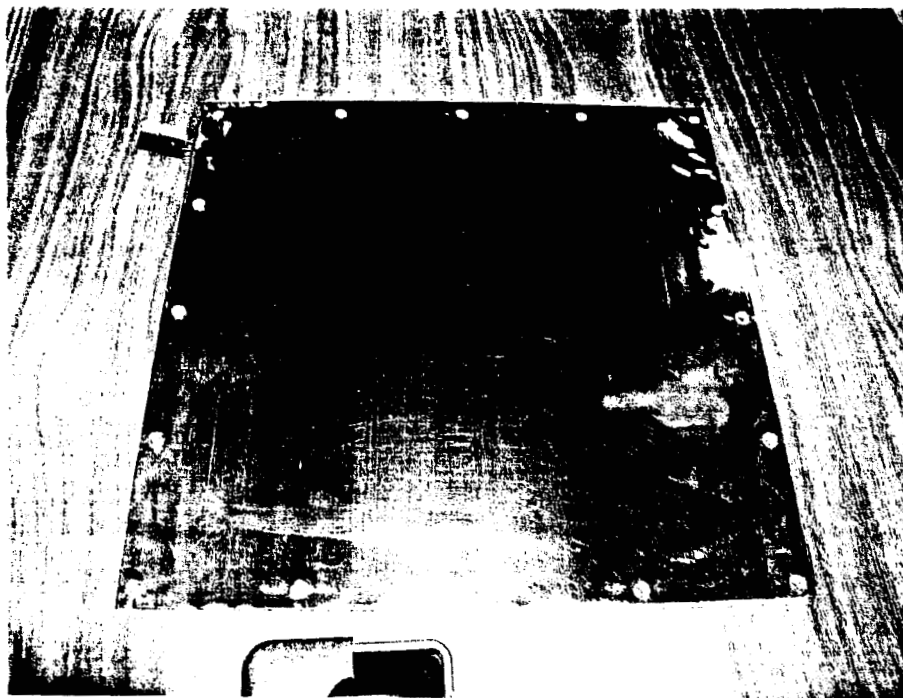
Copper/NuSil 1



- 5 mil Cu sheet
- 5 mil Cu picture frame (taped up)
- 1" separation between strips

*Center: 0.10 W/(in²*K)*

*Perimeter: 0.40 W/(in²*K)*





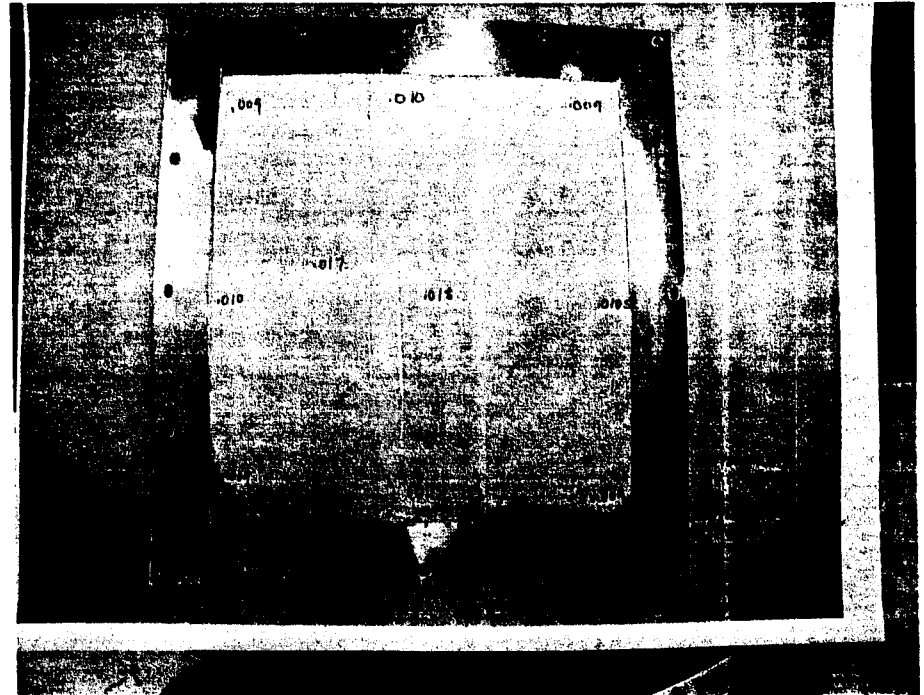
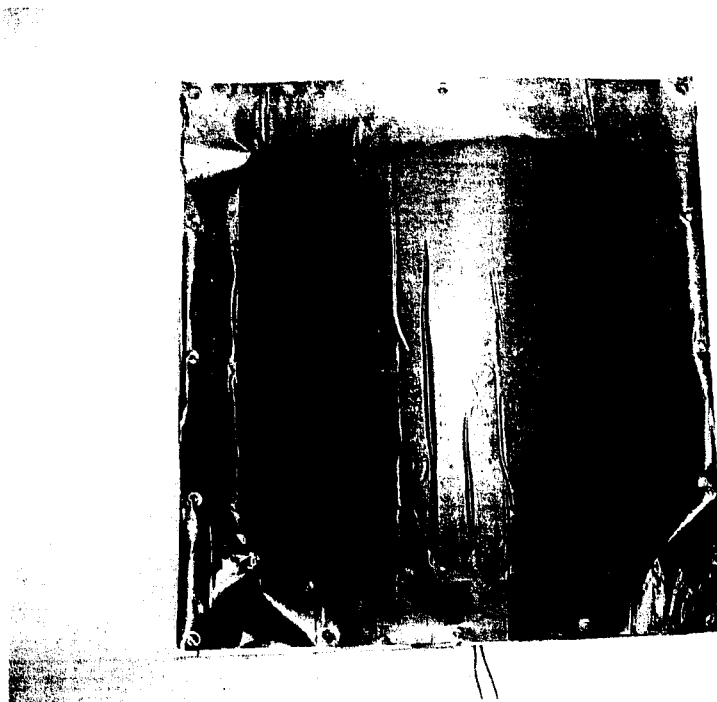
Copper/NuSil 2



- 1/2 mil Cu sheet
- 6 mil Cu picture frame (cut)
- 3/4" separation between strips

Center: $0.10 \text{ W}/(\text{in}^2 \cdot \text{K})$

Perimeter: $0.33 \text{ W}/(\text{in}^2 \cdot \text{K})$





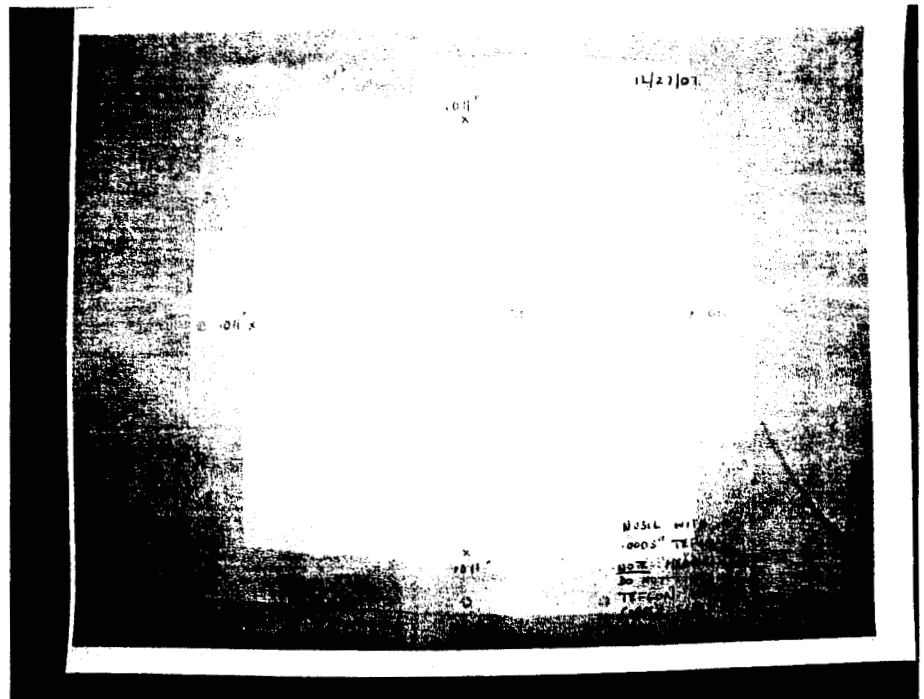
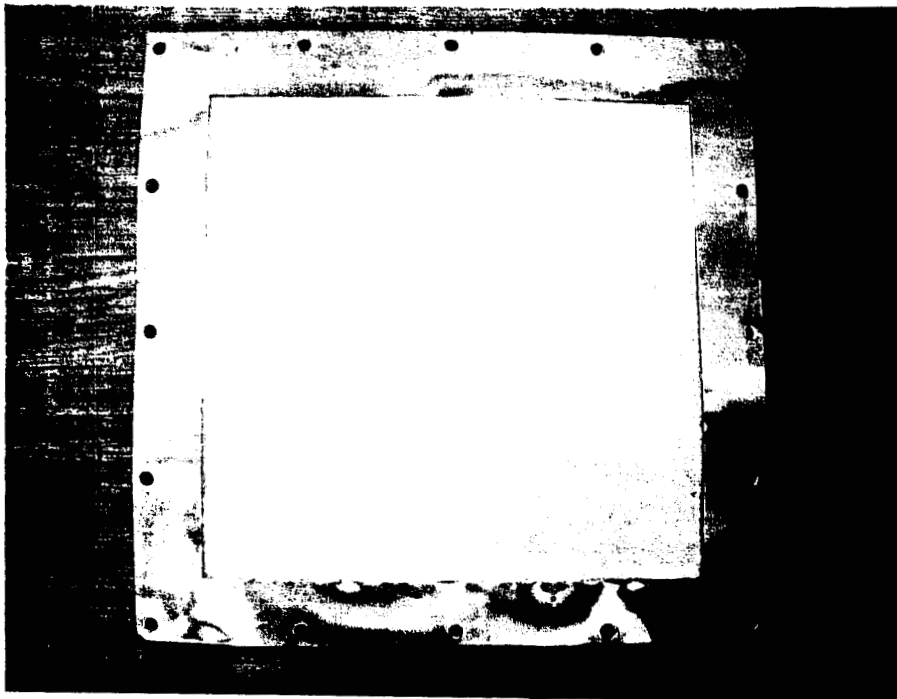
Copper/Nusil 3



- 5 mil Teflon film
- 6 mil Cu picture frame (cut)
- 3/4" separation between strips

Center: $0.22 \text{ W}/(\text{in}^2 \cdot \text{K})$

Perimeter: $0.82 \text{ W}/(\text{in}^2 \cdot \text{K})$





Results



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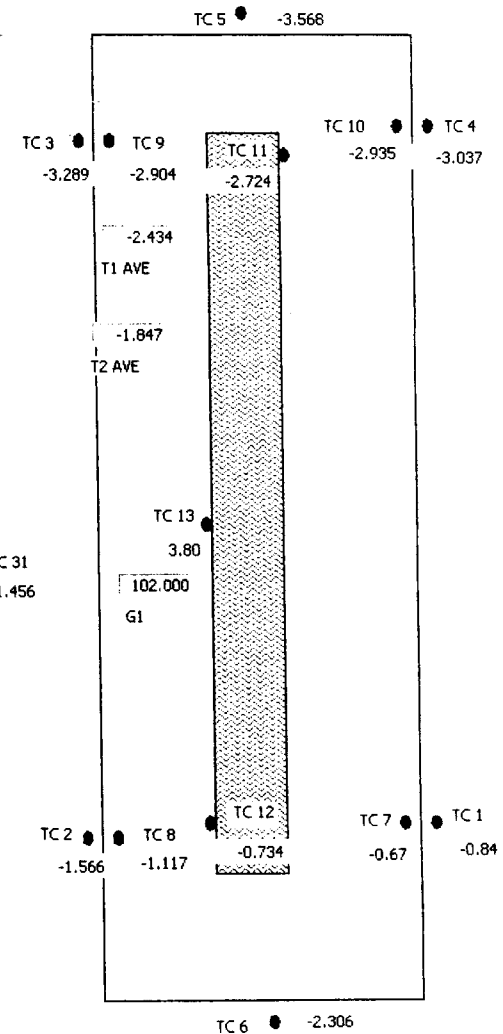
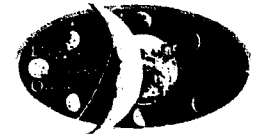


Results



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Interface Conduction Calculation



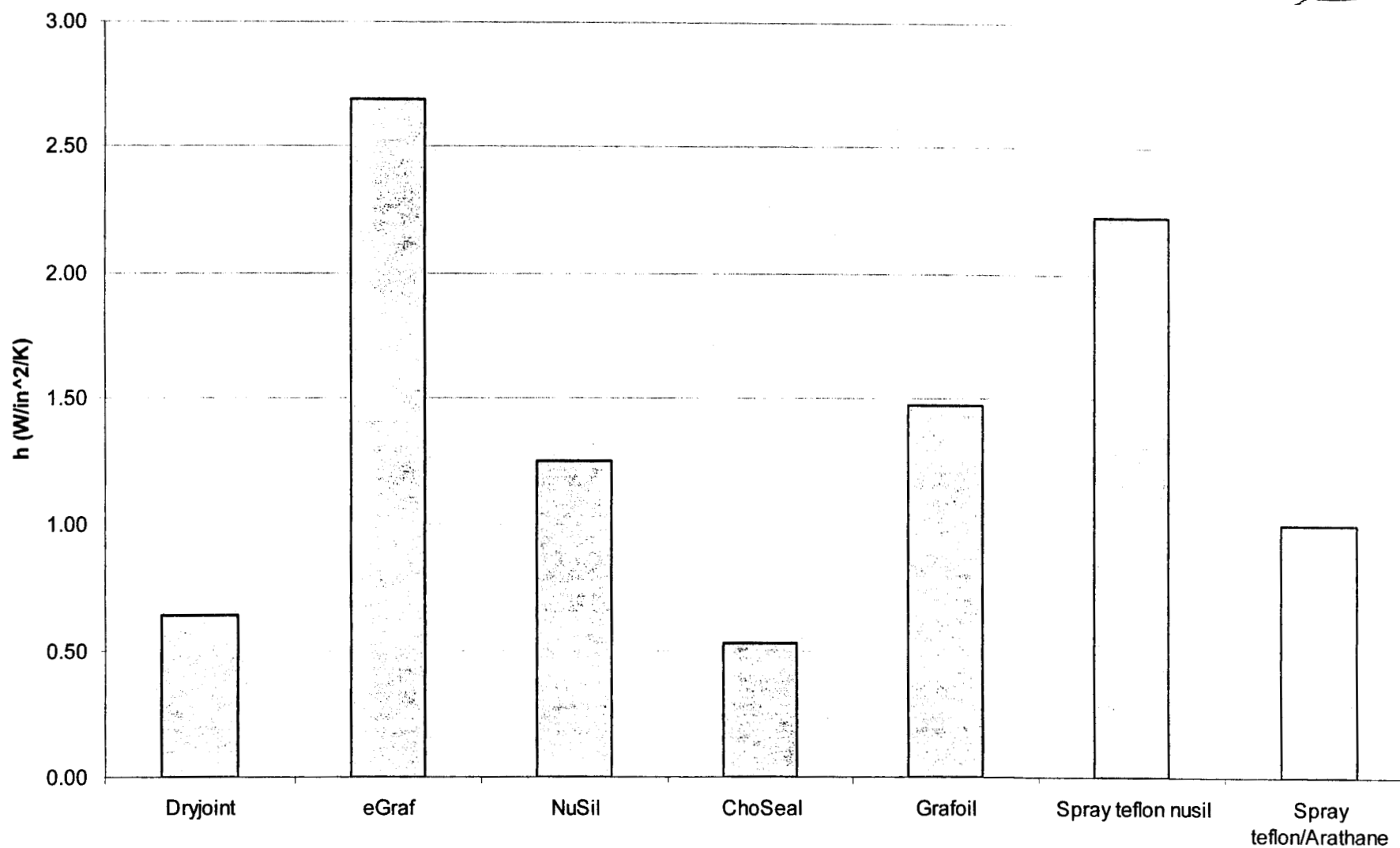
$$G1 := \frac{Q_{\text{diss}}}{(T_{\text{surface}} - T_{\text{sink}}) \cdot \text{Area}}$$

Units: W/(in²*K)



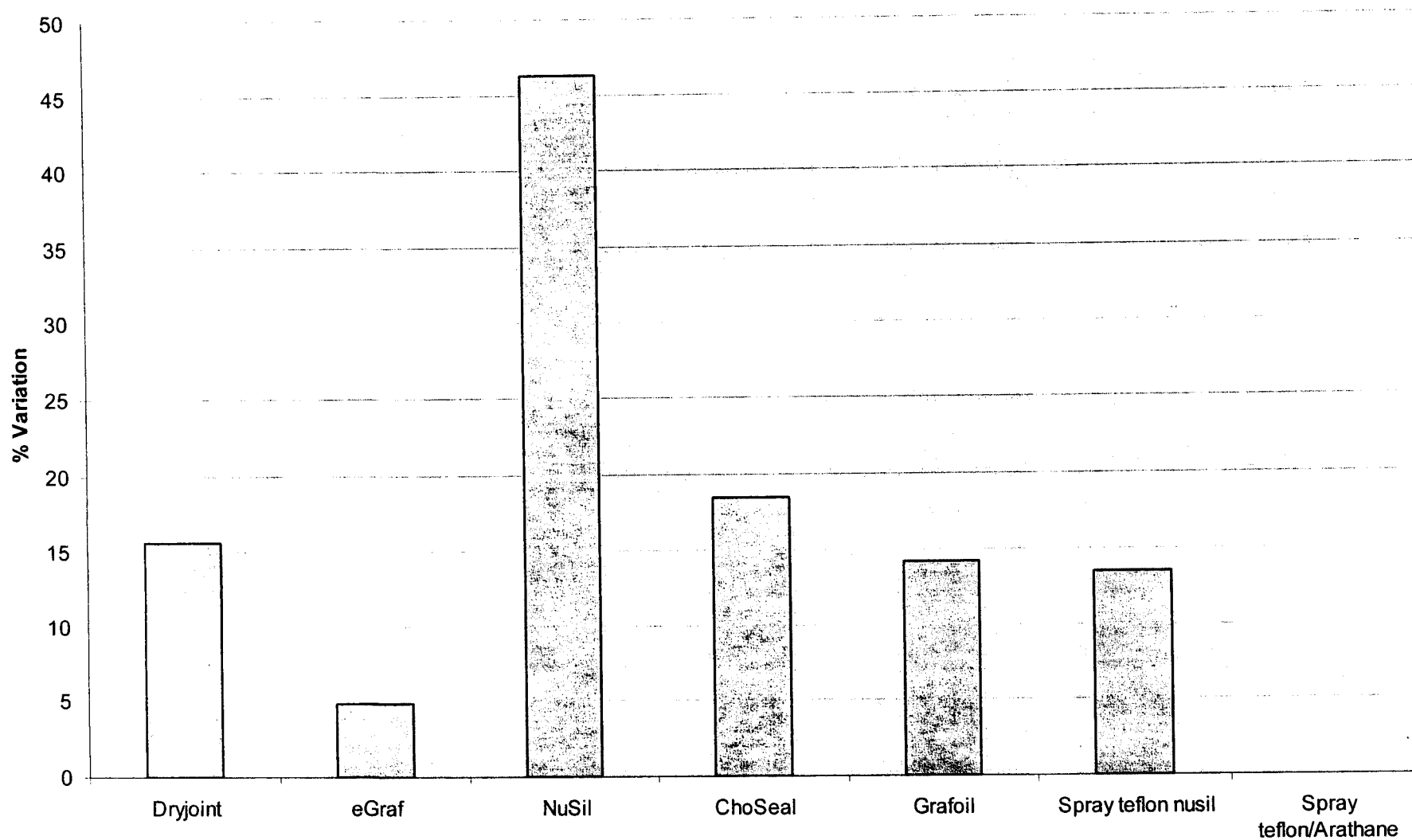


Heat Pipe interface conductance



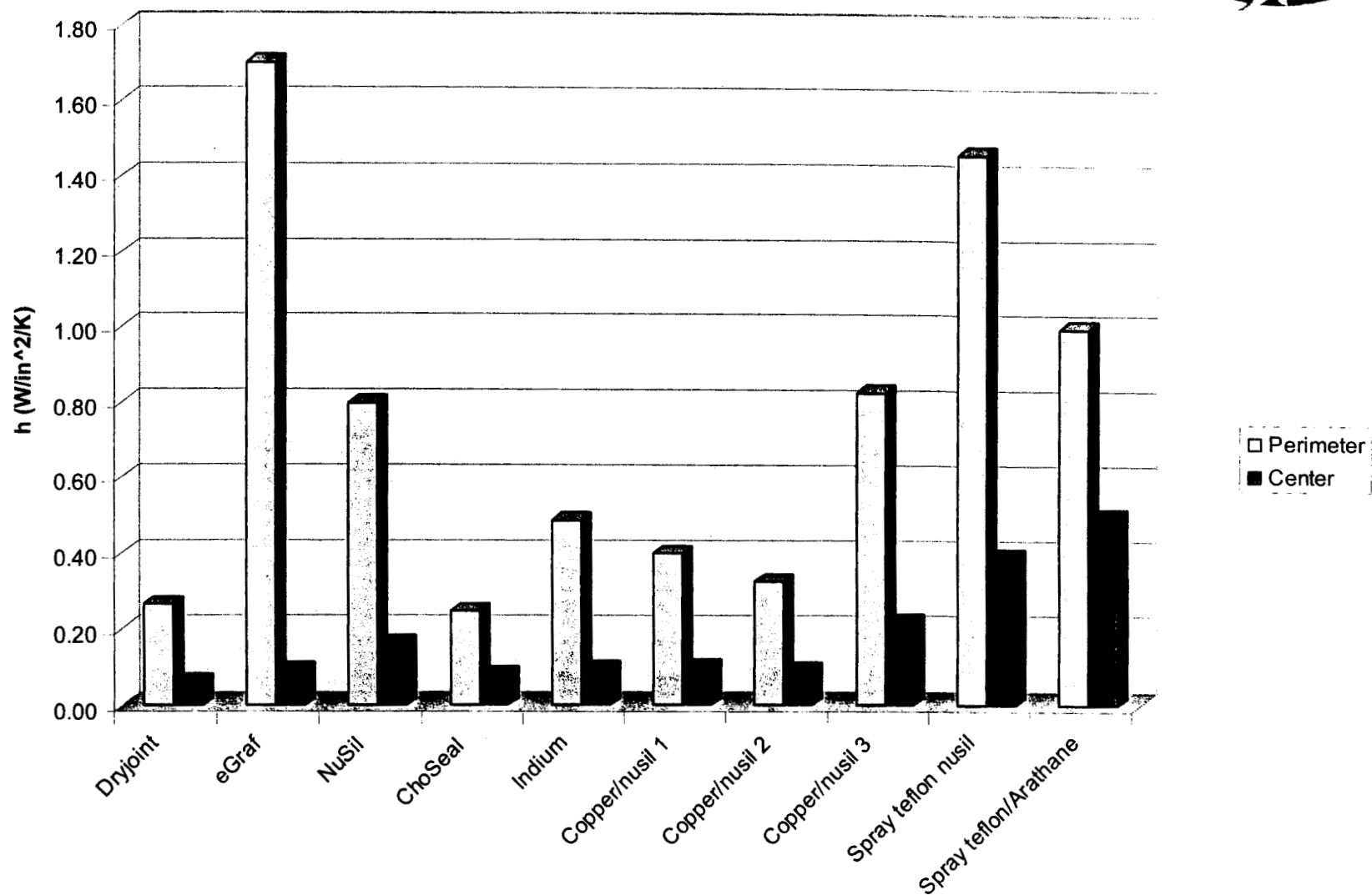


Heat Pipe % Variation



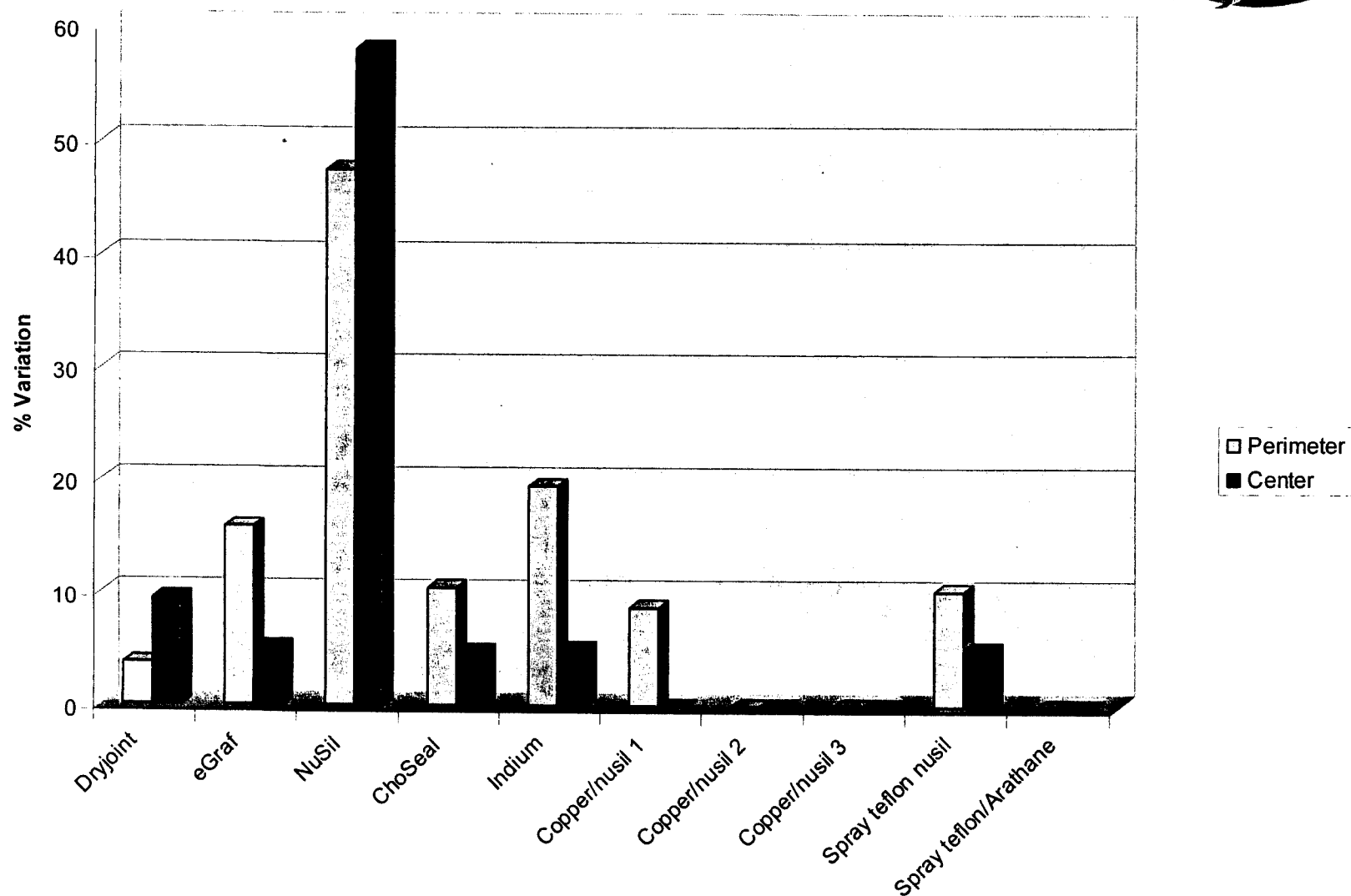


Baseplate interface conductance



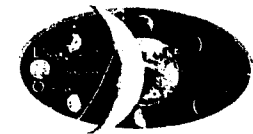


Baseplate % Variation





Conclusions



- Superiority of NuSil in areas not bolted down vs. solid sheets
- Exceptional performance of eGraf around bolted areas and all around in stiffer surfaces
- On picture frame variation it was found that copper frame did not enhance the perimeter thermal conductance. Performance was best when thin teflon sheet was used instead of copper
- Undergoing supplemental tests
 - Nusil with spray teflon
 - Arathane loaded with 60% Boron Nitride with spray teflon

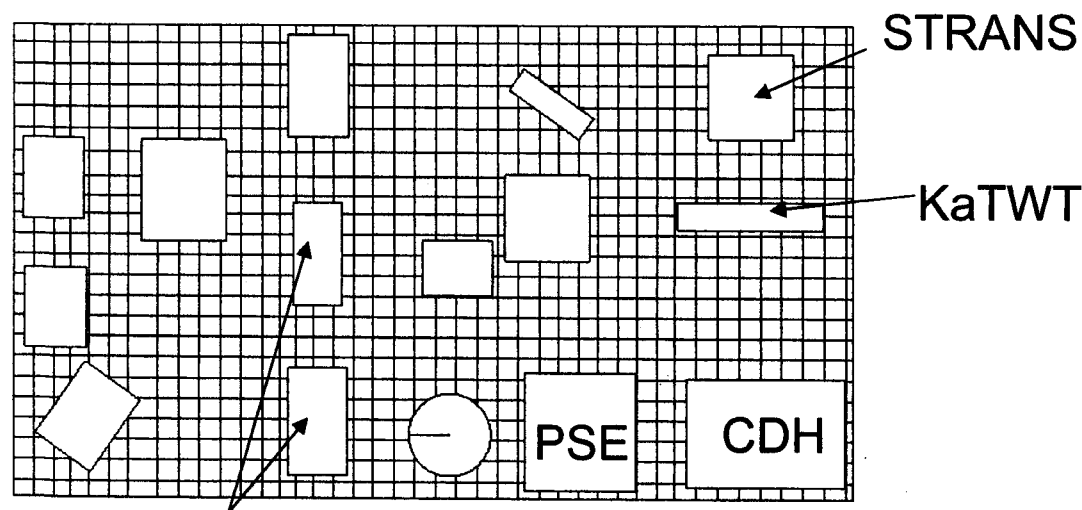




Implementation



- Avionics on ITP panel
 - CDH, PSE, STRANS (Copper picture frame with NuSil)
 - MiniRF receiver and controller, possibly KaTWT (eGraf)



MiniRF receiver & controller

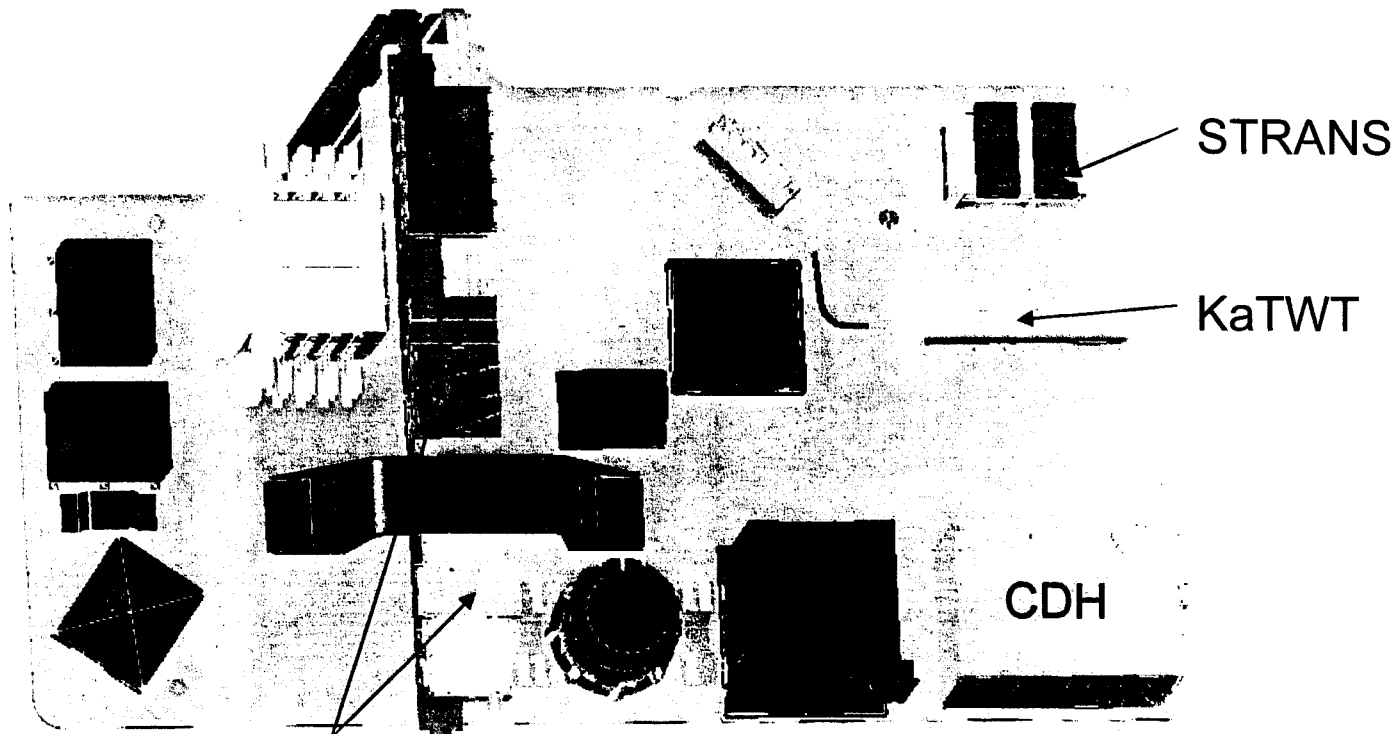




Implementation



- Avionics on ITP panel
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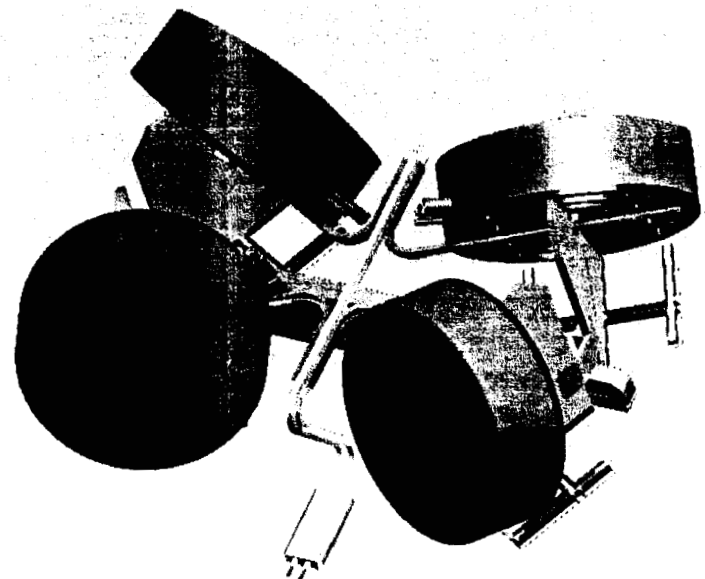
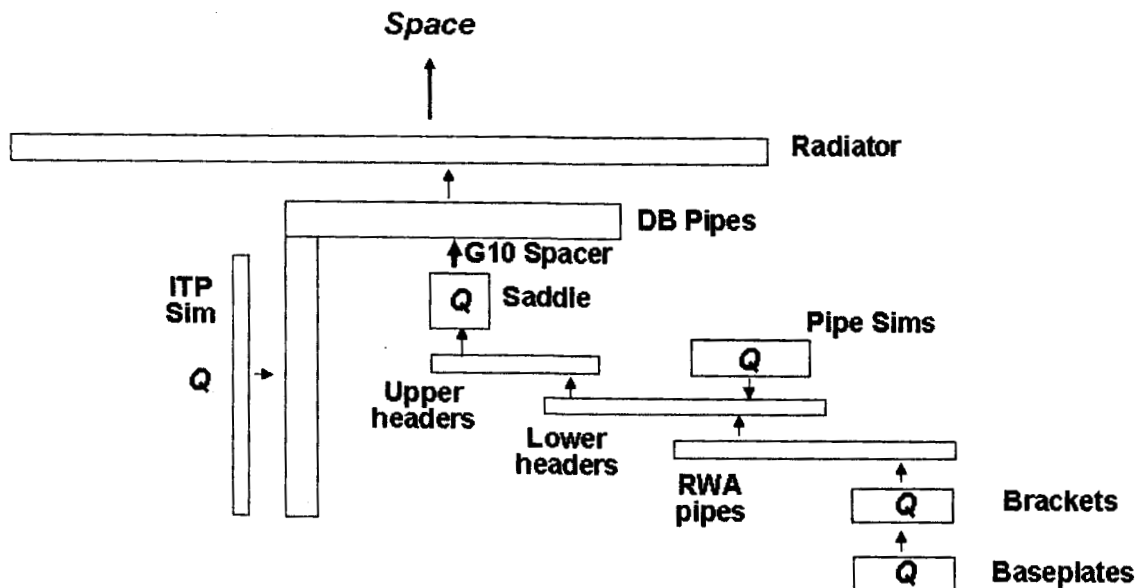




Implementation



- Heat pipe interfaces
 - RWA heat pipe joints (eGraf)
 - Dual bore heat pipes to radiator (eGraf)





Appendix



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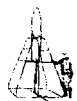
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Heat Pipe



		Dry joint	eGraf	NuSil	ChoSeal	Grafoil
Cold sink	Low power	0.60	2.62	1.00	0.57	
	High power	0.61	2.75	1.18	0.58	1.37
Hot sink	Low power	0.70			0.48	
	High power	0.65		1.58	0.49	1.58





Baseplate



Baseplate Perimeter		Dry joint	eGraf	NuSil	ChoSeal	Indium
Cold sink	Low power	0.26	1.67	0.74	0.26	
	High power	0.26	1.58	0.64	0.26	0.44
Hot sink	Low power	0.27			0.24	
	High power	0.27	1.85	1.02	0.23	0.54
Baseplate Center		Dry joint	eGraf	NuSil	ChoSeal	Indium
Cold sink	Low power	0.06	0.09	0.14	0.08	
	High power	0.06	0.09	0.13	0.08	0.10
Hot sink	Low power	0.07			0.08	
	High power	0.07	0.10	0.22	0.08	0.10

